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NOVEL SPACERS FOR LIQUID CRYSTAL DISPLAYS

## BACKGROUND OF THE INVENTION

## (1) FIELD OF THE INVENTION

The invention relates to a method for forming spacers to provide substrate separation in Liquid Crystal Display structures. The spacers comprise positive photoresist pads formed on opaque pads. The positive photoresist pads are formed using the opaque pads as a mask and are self aligned to the opaque pads. Multiple layers of positive photoresist pads can be used to provide sufficient spacer height.

## (2) DESCRIPTION OF THE RELATED ART

In Liquid Crystal Displays a liquid crystal material is disposed between two parallel transparent substrates. These transparent substrates must be separated

uniformly across their entire area. A number of spacers uniformly distributed between the transparent substrates are usually used to provide uniform separation.

a U.S. Pat. No. 5,328,728 to Swirbel et al. and U.S. Pat. No. 5,389,288 to Rindo et al. teach methods of providing Liquid Crystal Display spacing using ball type spacers. U.S. Pat. No. <sup>5,379,139</sup> to Sato et al. shows the use of photoresist pillars as spacers but does not teach how the pillars are formed. U.S. Pat. No. 5,338,240 to Kim teaches the use of elongated spacers placed out of the display regions.

In the invention of this Patent Application spacers uniformly distributed between the transparent substrates of a Liquid Crystal Display are used to provide the separation between the transparent substrates of the Liquid Crystal Display. The spacers comprise positive photoresist pads formed on opaque pads. The positive photoresist pads are formed using the opaque pads as a mask and are self aligned to the opaque pads. The self alignment of the positive photoresist pads to the opaque pads allows several layers of positive photoresist pads to be used to provide the separation required for the Liquid Crystal Display.

## SUMMARY OF THE INVENTION

In liquid crystal displays, a liquid crystal material is disposed between a first surface of a first transparent substrate and a first surface of a second transparent substrate. The first surface of the first transparent substrate is parallel to the first surface of the second transparent substrate and separated from the first surface of the second transparent substrate by a number of spacers. The spacers must be able to provide a separation of between about 4 and 12 microns between the first surface of the first substrate and the first surface of the second substrate. The spacers must be uniformly distributed over the surfaces being separated to provide a high degree of parallelism between the surfaces and prevent bowing of the substrates. It is very desirable to have a high degree of flexibility in the size of the spacers and therefore in the resulting separation between the substrate surfaces.

A prior art method of forming spacers is shown in Figs. 1A-1D. Fig. 1A shows base pads 11 formed on a first surface 16 of a substrate 10. As shown in Fig. 1B, a layer of spacer material 12 is formed on the first surface 16 of the transparent substrate 10 and a layer of photoresist 14 is formed on the layer of spacer material 12. Using

photolithographic methods, first spacers 13 are formed on the base pads 11, as shown in Fig. 1C. The first spacers 13 are not self aligned to the base pads 11 and misalignment can occur. As shown in Fig. 1D, second spacers 15 can be formed on the first spacers 13 if required for added spacer height. As more spacer layers are added the alignment problems become more severe.

It is a principle objective of this invention to provide a method of forming spacers between substrate surfaces in a liquid crystal display which can provide a wide range of separation distances by using self aligned spacer layers and which can be formed in a low cost process.

It is a further objective of this invention to provide a liquid crystal display structure using spacers to provide separation between the two facing substrate surfaces of the display wherein the spacers are low cost and provide a wide range of separation distances.

These objectives are achieved by forming a number of opaque pads, formed of a material such as chromium, molybdenum, or aluminum, on a first surface of a first transparent substrate. A layer of positive photoresist is then formed over the first surface of the first substrate covering the opaque pads. The positive photoresist is then

exposed by means of a light beam through the second surface of the first substrate thereby using the opaque pads as a mask. The positive photoresist is then developed leaving a layer of photoresist on the opaque pads. This layer of photoresist on the opaque pads can then be used as a spacer or a second layer of photoresist can be formed over the first surface of the first substrate. The photoresist is again exposed by a light beam passing through the second surface of the first substrate. The photoresist process can be repeated as many times as necessary until the desired spacer height is reached. The layers of photoresist on the opaque pads are self aligned to the opaque pads.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A shows a cross section view of base pads on a transparent substrate for a prior art method of forming spacers.

Fig. 1B shows a cross section view of a layer of spacer material and a layer of photoresist formed on a transparent substrate with base pads for a prior art method of forming spacers.

Fig. 1C shows a cross section view of prior art spacers formed of a base pad and one layer of spacer material on a transparent substrate.

Fig. 1D shows a cross section view of prior art spacers formed of a base pad and two layers of spacer material on a transparent substrate.

Fig. 2 shows a cross section view of opaque pads formed on a first surface of a transparent substrate for the method of this invention.

Fig. 3 shows a cross section view of a first layer of positive photoresist formed on a transparent substrate covering the opaque pads, with the light beam exposing the first layer of positive photoresist through the second surface of the transparent substrate.

Fig. 4 shows a cross section view of the first photoresist pads formed on the opaque pads.

Fig. 5 shows a cross section view of a second layer of positive photoresist formed on a transparent substrate covering the opaque pads, with the light beam exposing the second layer of positive photoresist through the second surface of the transparent substrate.

Fig. 6 shows a cross section view of the second photoresist pads formed on the first photoresist pads and the opaque pads.

Fig. 7 shows two transparent substrates with liquid crystal material disposed between separated by the spacers of this invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Refer now to Figs. 2-7, there is shown the principle embodiment for forming the spacers of this invention. As shown in Fig. 2, opaque pads 21, formed from a material such as chromium, molybdenum, or aluminum and having a thickness between about <sup>500 and 2000</sup>~~1000 and 2000~~ Angstroms, are formed on a first surface 50 of a first transparent substrate 20. <sup>a</sup> Next, as shown in Fig. 3, a first layer of positive photoresist 22 <sup>a1</sup> is formed on the first surface 50 of the first transparent substrate 20 covering the opaque pads 21. <sup>a2</sup> A light beam 30 is then passed through the second surface 51 of the first transparent substrate 20 to expose the first layer of positive photoresist 22. The opaque pads 21 act as a mask so that when the exposed first layer of positive photoresist 22 is developed photoresist remains only on the opaque pads 21 forming a first photoresist pad 23, see Fig. 4. The first photoresist pads 23 are self aligned to the opaque pads 21 so that there are no alignment problems. Depending on the height requirements of the spacers the spacers can be formed from the opaque pads 21 and the first photoresist pads 23 as shown in Fig. 4.

If greater spacer height is required a second layer of positive photoresist 24 <sup>a3</sup> is formed on the first surface 50 of the first transparent substrate 20 covering



the opaque pads 21 and the first photoresist pads 23, as shown in Fig. 5. A light beam 30 is then passed through the second surface 51 of the first transparent substrate 20 to expose the second layer of positive photoresist 24. The opaque pads 21 act as a mask so that when the exposed second layer of positive photoresist 24 is developed photoresist remains only on the first photoresist pads 23 forming second photoresist pads 25, see Fig. 6. The second photoresist pads 25 are self aligned to the opaque pads 21 and the first photoresist pads 23 so that there are no alignment problems.

As shown in Fig. 6, depending on the requirement for the spacer height 28, the spacers can be formed from the opaque pads 21, the first photoresist pads 23, and the second photoresist pads 25. A spacer height 28 of between about 4 and 12 microns is usually required for liquid crystal displays.

way More levels of photoresist, not shown, can be added using the same method as described above if required to provide sufficient spacer height. Since each layer of photoresist pad is self aligned to previous layers, six or more layers of photoresist pads can be used to provide sufficient spacer height without alignment problems.

As shown in Fig. 7, a second substrate 40 having a first surface 53 is then brought together with the first transparent substrate 20 so that the first surface 53 of the second substrate 40 contacts the spacer formed on the first surface 50 of the first transparent substrate 20. In this example the first surface 53 of the second substrate 40 contacts the second photoresist pads 25 but it will be readily apparent to those skilled in the art that the spacer could have more or fewer photoresist pad layers. The space 42 between the first surface 53 of the second substrate 40 and the first surface 50 of the first transparent substrate 20 is then filled with a liquid crystal material. The second substrate 40 can be transparent if desired.

Refer now to Fig. 7, there is shown an embodiment of a liquid crystal display structure using spacers provided by this invention to provide spacing between the opposing surfaces of the substrates of the liquid crystal display. Opaque pads 21, formed of a material such as chromium, molybdenum, or aluminum, are formed on a first surface 50 of a first transparent substrate 20.

First photoresist pads 23, formed of a positive photoresist material, are formed on the opaque pads 21. Since the first photoresist pads 23 are formed using the opaque pads 21 as a mask they are self aligned to the opaque

pads 21. If required for spacer height, second photoresist pads 25, formed of a positive photoresist material, are formed on the first photoresist pads 23. Since the second photoresist pads 25 are formed using the opaque pads 21 as a mask they are self aligned to the opaque pads 21. Depending on the requirements for the spacer height 28 the spacer may nor include the second photoresist pads 25 or additional layers of photoresist pads, not shown, may be used. Because all layers of photoresist pads are self aligned to the opaque pads 21 as many as six or more layers of photoresist pads can be used without alignment problems.

A first surface 53 of a second substrate 40 is then brought into contact with the spacers, in this example the second photoresist pads 25, to provide a separation distance 28 between the first surface 50 of the first transparent substrate 20 and the first surface 53 of the second substrate 40. The separation distance 28 is between about 5 and 12 microns. The space 42 between the first surface 50 of the first transparent substrate 20 and the first surface 53 of the second substrate 40 is filled with a liquid crystal material. The second substrate 40 can be transparent if desired.

While the invention has been particularly shown and described with reference to the preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the invention.

What is claimed is: